Prepared for:
Tronox LLC
Nevada

Annual Remedial Performance Report for Chromium and Perchlorate, Tronox LLC, Henderson, Nevada

July 2007 – June 2008

Submitted in Accordance with 1986 Chromium Consent Order and 2001 Perchlorate Administrative Order on Consent

Prepared by:
ENSR and Tronox LLC
August 28, 2008

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Henderson, Nevada

Responsible CEM for this project

I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.

SM Crowley 8-25-08

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Acronyms and Abbreviations

AOC	Administrative Order and Consent
Barrier wall	On-site bentonite-slurry groundwater barrier wall
BMI	Black Mountain Industries
CD	Compact disk
COH WRF	City of Henderson Water Reclamation Facility
Cr	Chromium
ECA	Environmental Compliance Assessment
FBR	Fluid Bed Reactors
gpm	gallons per minute
GPS	global positioning system
GWTP	Groundwater Treatment Plant
mg/L	milligrams per liter
mm gals	million gallons
MRL	Method Reporting Limit
ND	non-detect
NDEP	Nevada Division of Environmental Protection
NPDES	National Pollutant Discharge Elimination System
POSSM	Pioneer/Olin Chlor-Alkalai/Stauffer/Syngenta Montrose
ppb	parts per billion
RIB	Rapid Infiltration Basin
SNWA	Southern Nevada Water Authority
TDS	total dissolved solids
Tronox	Tronox LLC
UIC	Underground Injection Control

1.0 INTRODUCTION

In accordance with the Consent Order for remediation of chromium-impacted groundwater at the Henderson facility, finalized September 9, 1986 and the Administrative Order on Consent (AOC) for remediation of perchlorate-impacted groundwater in the Henderson area, finalized October 8, 2001, Tronox LLC (Tronox) submits this remedial performance report to the Nevada Division of Environmental Protection (NDEP).

This report, covering the period July 2007 through June 2008, summarizes performance data for both the chromium and perchlorate remediation programs. Specifically, this report describes:

- the regional groundwater conditions based on May 2008 groundwater levels;
- the hexavalent chromium remediation system and the effectiveness of the groundwater capture and treatment system installed to carry out the chromium remediation program; and
- the perchlorate remediation system (consisting of the on-site Interceptor well field, the off-site Athens Road well field, the off-site Seep well field and the off-site Seep surface-flow capture sump) and the effectiveness of the groundwater capture and treatment system installed to carry out the perchlorate remediation program.

In addition, the report describes the chromium remedial activities at the Athens Road well field, provides information on the status of the perchlorate treatment technologies and contains data requirements relevant to the chromium remediation system's Underground Injection Control (UIC) permit modification.

Other activities that occurred during the reporting period included:

- Refurbishing the injection trenches and
- Installation of additional wells to further evaluate capture.

The annual groundwater sampling (completed in the second calendar quarter) has developed into a robust event in which data from groundwater samples, collected by neighboring companies, are incorporated into the Tronox potentiometric, total chromium, and perchlorate maps. Additionally, annual maps have been created showing the total dissolved solids (TDS), chlorate and nitrate concentrations combining the available data provided by the other companies. Tronox received information from Pioneer/Olin Chlor-Alkali / Stauffer/ Syngenta / Montrose (POSSM) and Southern Nevada Water Authority (SNWA) and their data were integrated into Tronox's to develop these maps. In addition, previously distributed data from TIMET collected in the time period January to February 2008 were used to supplement some of the maps.

This report is provided as a hard copy report and on a compact disk (CD). Where electronic files are referenced, or information is stated as "provided on CD," this information is contained on the complete report CD inserted at the front of the report. Appendix A contains an Access © compatible data file with five quarters of analytical data (on the report CD). The effectiveness of the groundwater capture systems is addressed in a separate report, *Groundwater Capture Evaluation* at *Tronox Extraction Systems* attached as Appendix B. Appendix C contains the laboratory reports and field sheets (on the report CD). Appendix D contains correspondence with NDEP including responses to comments on previous Tronox reports and Appendix E contains the analytical data review memorandum

Figure 1, a location map covering the area between the Tronox facility and Las Vegas Wash, shows the components of the remedial systems with an index of accompanying large-scale plates and sections. The performance of each component will be discussed separately in this report starting with the on-site Interceptor well field and proceeding to the successively northward components. Plate 1 shows the locations of all wells in the mapped area.

2.0 AREA GROUNDWATER CONDITIONS

Plate 2, the *Potentiometric Surface: Tronox Site to Las Vegas Wash,* is based on groundwater elevation measurements taken in May 2008 by Tronox and POSSM and January/February 2008 by TIMET and shows a generally north-northeast groundwater flow direction with an average gradient of 0.02 feet per foot south of the Athens Road well field flattening to 0.007 feet per foot north of the well field.

On the map's southern end, beneath the Tronox facility, the flow direction is generally north-northwesterly, whereas north of the facility the direction changes slightly to the north-northeast. This generally uniform flow pattern has been modified locally by subsurface alluvial channels cut into the underlying Muddy Creek formation surface, the on-site bentonite-slurry groundwater barrier wall (barrier wall), on- and off-site artificial groundwater highs or "mounds" created around the recharge trenches and infiltration ponds, and by "low areas" created by the groundwater recovery wells at the three groundwater recovery well fields.

2.1 Interceptor Well Field Area

The Interceptor well field area is shown on Figure 1 and Plate 2. Plate 2 shows that the potentiometric surface behind (upgradient of) the barrier wall is in the top of the fine-grained facies of the Muddy Creek formation (except in narrow localized alluvial channels) whereas from about the barrier wall northward it is in the alluvium. North of the barrier wall, water elevations in wells M-69 through M-74 range between two to seven feet lower than water elevations south of the barrier wall indicating negligible hydraulic communication across the barrier wall. Inset B on Plate 2 shows the redeveloping groundwater mound in the vicinity of wells M-70, M-80 and M-83 from introduced Lake Mead water in the recharge trenches north of the barrier wall. In this area, the groundwater is artificially recharged with lake water in two gravel-filled trenches to balance the loss of groundwater removed from the alluvium and Muddy Creek formations by the Interceptor well field.

In March/April 2008, the gravel in the north trench was excavated and old gravel, tree roots, Quagga mussels and minor amounts of iron oxide were removed. These materials were removed from the full length, width and depth of the north trench which is approximately 760 feet long, three to four feet wide and 15 feet in depth. The excavated material was placed adjacent to the trench. Clean, washed, ¾ -inch gravel was placed in the trench. Plans to install a filter to prevent the introduction of Quagga mussels into the refurbished trench were completed. Once the filter comes on line Tronox will resume flow to the north trench.

During the trench refurbishing and at present, clean (less than 5 parts per billion [ppb] perchlorate) Lake Mead water has been put in the south trench. Tronox also opened an area adjacent to the introduction point for the south trench so when the first standpipe in the south trench over flows, the water is still contained and will infiltrate in the immediate area. In May 2008, the monthly average water discharged to the south trench and the open area increased to 60.7 gallons per minute (gpm).

Figure 2, the *East – West Hydrogeologic Cross Section - Interceptor Well Field*, shows the current water levels in the pumping Interceptor wells, adjacent monitor wells and the relationships between the pre-pumping and current groundwater level. Between June 2, 2008 and June 4, 2008,' eight of the pumping wells were turned off until static water levels were reached. Water elevation readings were taken of the static levels, which are shown on the section. The section also shows the series of narrow subparallel alluvial channels separated by Muddy Creek ridges, many of which are above the current groundwater level. Recent installation of new wells on both ends of the barrier wall has affirmed the presence of inter-channel Muddy Creek ridges at both ends of the barrier wall. The tops of these bounding ridges are shown in the section to be above the adjacent potentiometric surface – separating the saturated alluvium at Timet well CLD2-R from Interceptor well I-K on the east. On the west a new channel, discovered west of abandoned well I-A, is separated from well I-B by the remnants of a Muddy Creek ridge. The contact between the alluvium and the Muddy Creek at the bottom of this new channel is present about five feet below the contact in adjacent well M-57A.

Currently, the water elevations in many of the pumping Interceptor wells are below the Muddy Creek formation contact, whereas the water levels in adjacent monitor wells are higher in the alluvium. These differences can be attributed to well inefficiencies due to the low permeabilities of the fine-grained Muddy Creek formation and general lack of saturation in the alluvium. Because of the low permeability of the Muddy Creek, very little water is entering the screens below the contact, leaving the only significant source of water to the wells to be cascading water from the overlying alluvium. This scenario is complicated by the fact that hard caliche layers are common at the formational contact across the well field, further inhibiting groundwater flow into the wells (see cross section for location of calichfied zones). In the period between December 2007 and February 2008, Tronox videotaped and redeveloped 22 of 23 Interceptor wells. Results of this work appear in Table 2 of the accompanying report *Groundwater Capture Evaluation* (Appendix B). Most wells had an improvement in pumping capacity whereas others had none. The goal of the Interceptor well system is not necessarily to dewater the alluvium at each well but to control and influence groundwater in the saturated intervals between the Interceptor wells.

The monthly average discharge rate for each Interceptor well during June 2008 is shown on Table 1. This table compares the June discharge data to the same time period each year from to June 2003 to June 2008. These discharge data illustrate the gradual increase in groundwater capture after the barrier wall was installed in October 2001. The June 2008 total discharge was 61.1 gpm.

2.2 Athens Road Field Area

The Athens Road well field was completed in March 2002 and groundwater collection in this area began shortly thereafter. Continuous pumping from this well field began in mid-October 2002. More recently, in early September 2006, an additional recovery well (ART-9) began full-time pumping. Figure 1 and Plate 2 show the location of the Athens Road well field. Recent mapping of the May 2008 groundwater elevations is shown on Plate 2, the *Potentiometric Surface* map. In this well field area, the map shows the Main alluvial channel trending generally north-northeast toward the Wash. Inset A on Plate 2 shows the interpreted groundwater inflow (closed 1590-foot contour) surrounding the western part of the well field. Note that the groundwater elevation in ART-3 is 1.9 feet lower than in PC-135, located 38 feet to the north (i.e.1586.8 feet versus. 1588.7 feet), demonstrating inward flow. In the eastern part of the well field, however, the data show that the groundwater elevation in the area of ART-9, ART-7, and PC-136 is flat with the groundwater elevation in ART-7 being 1584.3 feet whereas the water elevation in PC-136 is 1584.2 feet. Tronox is pursuing ideas to demonstrate inward flow in the area and these will be discussed in the *Groundwater Capture Evaluation* in Appendix B.

North of this well field, in the east-central portion of Section 36, large intermittent surface-water infiltrations from the City of Henderson Water Reclamation Facility (COH WRF) Rapid Infiltration Basins (RIBs) periodically form large groundwater mounds in the potentiometric surface. In this area the groundwater gradient decreases from an average of 0.020 feet per foot to less than 0.007 feet per foot.

Figure 3, the *East - West Hydrogeologic Cross Section - Athens Road Well Field*, shows hydrologic conditions at the time of groundwater sampling in May 2008 versus April 2002. Groundwater levels are currently as much as 12.9 feet lower than they were in 2002 before pumping began. This figure also shows the extent of erosion of the Muddy Creek formation and the subsurface channels filled with the alluvium. In this area, the Main Channel splits into two subchannels separated by a Muddy Creek basement ridge above which the alluvium is unsaturated. Figure 5 shows that drawdown has progressed to the point that wells ART-5 and PC-12 are currently dry.

In order to assess the effects of drawdown on land subsidence, a background global positioning system (GPS) survey was conducted in March 2002 by Stantec Consulting, Inc. using real-time kinematic techniques with Trimble 4000 SSI and 4700 receivers and a TSC1 data collector. Between May 2003 and May 2005, the well field had been resurveyed every six months to determine the extent of subsidence. Since May 2005, surveys were conducted in 2006 and 2008. Figure 6 shows the results of these surveys and illustrates that between March 2002 and June 2008 there has been up to 1.45 inches of subsidence (in ART-6) in the well field. The four wells with the most subsidence are identified. Well PC-12, which is between ART-5/ART-6 and the Pittman Lateral, shows no subsidence over the same period.

Recent recovery well discharge rates for the Athens Road Wells are shown on Table 2. This table shows that the June 2008 average discharge from the pumping Athens Road recovery wells (ART-2, 3A, 4A, 7, 8 and 9) was about 271 gpm. Discharge rate comparisons back to June 2003 are also provided in the table.

2.3 Seep Well Field Area

The Seep well field and the Seep stream pumping station are shown on Figure 1 and Plate 2. In July 2002 when pumping began, the Seep well field consisted of three recovery wells situated over the deepest part of the alluvial channel. In February 2003, five additional wells (PC-117 to PC-121) and in December 2004 one additional well (PC-133) were completed in the Seep well field area. Plate 2, the *Potentiometric Surface* map, shows that north of the Athens Road well field the gradient of the north-northeast sloping potentiometric surface decreases to about 0.007 feet per foot due to constant water infiltration from the COH Birding Ponds, periodic mounding events from the COH WRF, and underflow from Las Vegas Wash.

Figure 4, the *East - West Hydrogeologic Cross Section Seep Well Field*, shows that the alluvial channel is much less incised into the underlying Muddy Creek formation and that the configuration of the alluvial channel is a broad shallow feature about 800 feet wide and averaging about 45 feet thick. In May 2001, before pumping began, the groundwater level in the area was very shallow and would daylight every winter. This figure shows that in May 2002 the depth to water averaged about 1 foot below ground level in the Seep well field area, whereas in May 2008 drawdown due to pumping was up to 7.5 feet below pre-pumping levels (in monitor well PC-90).

Recent recovery well discharge rates for the Seep well field area are presented in Table 3. This table shows that the average discharge rate for June 2008 was a total of about 631 gpm. Discharge rate comparisons back to June 2003 are also provided. As shown in the table, the minor decrease in the discharge rate over the last four years is due to well field optimization efforts whereby discharge rates in wells and well fields with lower contaminant mass loading are preferentially decreased over wells and well fields with higher contaminant mass loading. The Seep stream has not flowed since mid-April 2007.

3.0 CHROMIUM MITIGATION PROGRAM

The four components of the chromium mitigation program (consisting of the on-site Interceptor well field, the groundwater barrier wall, the groundwater recharge trenches, and the off-site Athens Road well field) are shown on Figure 1. For the last twelve months - July 2007 to June 2008 - a total of about 4,081 pounds of chromium was captured, hexavalent chromium removed, and residual solids disposed of in a permitted landfill. Please note that for the discussion below, total chromium is conservatively considered to be entirely hexavalent chromium.

3.1 Chromium Plume Configuration

Plate 3, the *Total Chromium in Groundwater* map, shows the contoured total chromium groundwater plume from its on-site source northward to the point where the plume reaches non-detect levels south of Las Vegas Wash. South of the Interceptor well field the highest total chromium concentration occurred in well M-36 (37 milligrams per liter [mg/L]) whereas north of the recharge trenches the highest total chromium concentration found in the May 2008 sampling was 4.0 mg/L.

3.1.1 On-Site Interceptor Well Field Area

Figure 7, the *Interceptor Well Field Total Chromium Section Graph*, shows the concentrations of total chromium across the well field over the last five quarters. The figure shows that the chromium concentrations are little changed on either end of the well line, whereas large changes have occurred in the central part. Currently, chromium concentrations in wells I-T, I-U and I-H have stabilized, while chromium concentrations in well I-Q have dropped in half since February 2008.

In May 1990, monthly analyses for chromium were initiated in several wells located both up- and downgradient from the recharge trenches. The schedule of sampling frequency was modified to quarterly sampling beginning in the second half of 1997. Appendix A contains total chromium data for the last five quarters along with groundwater elevations for these wells.

Chromium concentration data from the five wells identified in Consent Order Appendix J (i.e., wells M-11, M-23, M-36, M-72, and M-86) are presented in graphical form in Figure 8. Monitoring well M-11, immediately downgradient from the former primary source area (Units 4 and 5), has continued a downward decline in chromium concentration since 1993. Well M-36, upgradient of the Interceptor well field and barrier wall, began declining in chromium concentration in late 2004 and has remained relatively steady in chromium concentration since 2006. This “steady state” condition may indicate that the main portion of the upgradient chromium plume has reached the area of M-36. Plate 3 shows that the southern end of the highest total chromium contour (30 mg/L) has moved north of the Chemstar property. Since 2006, the chromium concentration in M-86 has been increasing slightly, while at the same time the chromium concentration in M-72 has been decreasing slightly. An inspection of this area on Plates 2 and 3 indicates that the groundwater mounding caused by infiltration of Lake Mead water in the recharge trenches has decreased in the area of well M-86 to the point that has allowed groundwater upgradient in the “dead zone” area, specifically M-71 and M-72, to slowly move downgradient. This resulted in a decrease in total chromium in wells M-71 and M-72, and a corresponding increase in well M-86. With the north trench being recently refurbished, it is expected that the chromium concentration in M-86 will start decreasing again. Well M-23, located 1600 feet downgradient from the barrier wall, is also continuing to show declining total chromium concentrations. Well M-23 again was below 1 mg/L (0.73 mg/L) in the May 2008 sampling which represents the third lowest total chromium value noted in this well since sampling was initiated in January 1987.

Total chromium concentrations downgradient of the barrier wall and recharge trenches continue to decline. A comparison of these data shows consistent declines in chromium concentrations in the groundwater downgradient from the Interceptor well field and barrier wall, indicating that the groundwater recovery and barrier system is functioning as an effective barrier to migration of the main portion of the chromium plume. For example, M-100, located 700 feet north of the recharge trenches has gone from 9.2 mg/L total chromium in January 2002 to 0.26 mg/L in June 2008.

To answer questions concerning the possibility that groundwater trapped behind the barrier wall is moving around the ends of the wall, Tronox recently installed monitor wells at both ends of the barrier. A detailed discussion of the results of these installations is found in the accompanying *Groundwater Capture Evaluation* in Appendix B.

3.1.2 Athens Road / Seep Well Fields Area

The groundwater recovery system at Athens Road has a positive effect on the chromium plume concentration north of the well field. In this area, the groundwater plume flows around the sides of a Muddy Creek formation basement ridge. The total chromium plume on the west side of the ridge, which contains lower concentrations than on the east side of the ridge, is captured and stopped by the groundwater recovery wells. The plume on the east side of the ridge is significantly reduced in concentration by the recovery wells in that area as it flows to the north. Figure 3 shows total chromium concentrations for May 2008.

As shown in Figure 9, the *Athens Road Well Field Total Chromium Section Graph*, chromium concentrations in the western subchannel over the last year have been low relative to those in the eastern subchannel. A new recovery well, ART-9, was recently installed in this area to capture a narrow channel of high chromium-impacted groundwater that was moving through the recovery well field. A dramatic decline in chromium concentration occurred in well PC-122, which went from 1.5 to 0.10 mg/L between November 2006 and February 2007, and remains in the 0.08 to 0.09 mg/L range. This is probably the result of the pumping of ART-9. The chromium concentration in ART-9 has increased slightly from 1.1 mg/L in February 2008 to the current 1.4 mg/L. Chromium in newly installed well PC-136, located 47 feet north of ART-9, unexpectedly increased from 1.2 to 4.0 mg/L between February and May 2008. This anomalous occurrence will be closely monitored; however, this concentration will most likely be pulled back to ART-9 as the well continues to pump. Within the next two quarters, Tronox will put well ART-6 back on-line and recover additional groundwater from it. Chromium concentrations from the well field are treated at Lift Station #3 with ferrous sulfate to reduce the chromium to insoluble Cr III before the water is sent to the on-site treatment system.

As mapped on Plate 3, the 0.02 mg/L total chromium contour in the eastern part of section 36 is interpreted to wrap around PC-98R and PC-104. Higher chromium concentrations in PC-1, PC 4 and PC-58 in the western part of Section 31 are interpreted to be sourcing from a subsidiary channel from the Black Mountain Industries (BMI) ponds to the southeast. No chromium section graph was prepared for the Seep well field because all wells in the well field have contained less that 0.02 mg/L total chromium since data began to be collected in February 2006.

3.2 On-Site Chromium Treatment System

The operation and maintenance of the chromium reduction process was contracted to Veolia Water North America (formerly US Filter Operating Services) on August 1, 2003. Tronox retains responsibility for compliance with the terms of the Consent Order and the subsequent Underground Injection Control (UIC) Permit NEV94218. In December 1998, the UIC Permit for the Tronox chromium mitigation system was modified to allow for injection of Lake Mead water to maintain groundwater levels downgradient from the Interceptor well field. Table 4 contains the July 2007 to June 2008 process treatment data from the on-site Groundwater Treatment Plant (GWTP). In June 2008, the GWTP received a total of 2.64 million gallons of groundwater from the Interceptor well field (including about 25 gpm from GW-11) containing an average total chromium concentration of 13.4 mg/L. The groundwater treated by the GWTP, containing 0.006 mg/L of hexavalent chromium and 0.790 mg/L of total chromium, was pumped to two 150,000 gallon storage tanks (BT-40 and BT-45 in series). From the storage tanks, the water moves to the equalization tanks where the outflow from the GWTP is combined with water from the off-site recovery system. From the equalization tanks, most of the blended water flows through activated carbon beds before being filtered and pumped to the Fluidized Bed Reactors (FBRs) for treatment of perchlorate, chlorate, and nitrate. A small portion of the GWTP flow (1 to 3 gpm) is not pumped to the FBRs but instead is returned to the GW-11 pond in order to avoid running the underflow pump dry.

As shown in Table 4, since July 2007 the total chromium inflow concentration from the Interceptor wells to the GWTP is holding fairly steady in a range of 13.0 to 14.7 mg/L. The reduction of hexavalent chromium during the year has been very efficient based on the average monthly values. Total chromium outflow concentrations for the last twelve months ranged from 0.790 to 1.608 mg/l – still below the permitted discharge of 1.7 mg/L. It is suspected that as the GWTP is pushed to capacity more solids are being suspended in the water sampled for the total chromium effluent analyses. It is also suspected that these solids contain Cr III precipitates which report as total chromium in the analyses. These solids do not make it to the final discharge of the remediated groundwater, but get retained in the granular, activated, carbon filter and/or settle out in the equalization tank. These overall data indicate that the chromium treatment process is working effectively. For the period between July 2007 and June 2008, about 3,605 pounds of chromium have been removed from the groundwater (Table 4).

Results of chromium analysis from weekly FBR influent and effluent samples are presented in Table 5. These data, from July 2007 to June 2008, show that the influent total chromium concentrations varied from less than 0.01 to 0.57 mg/L. Based on an average concentration of about 0.111 mg/L total chromium and an average flow rate of 975 gpm, the FBRs were receiving about 1.3 pounds of chromium per day from the equalization tanks.

Under an NPDES permit, treated water from the FBRs discharges to Las Vegas Wash just upgradient of the Pabco Road erosion control structure. Analyses of this water, from July 2007 and June 2008, appear in Table 5. All hexavalent chromium analyses, except two, have been non-detect at <0.0001 mg/l and that all total chromium analyses, except 15, have been non-detect at <0.01 mg/l. At an influent concentration of about 1.3 pounds per day, the FBR system removed an additional 476 pounds of chromium over the twelve month period. The sum of the chromium removed from the groundwater between July 2007 and June 2008 by the chromium recovery and treatment system and the FBRs is 4,081 pounds.

A diagram of the groundwater chromium system is presented on Figure 10. This block diagram is a life cycle presentation of chromium-impacted groundwater from the four primary groundwater collection areas, through the various treatment stages, and then to ultimate discharge as clean effluent to Las Vegas Wash.

3.3 Potential On-Site Interim Chromium Remediation

Tronox has reviewed the potential for interim chromium remediation activity at specific areas on-site. These areas include the impacted groundwater in the “dead zone” immediately downgradient of the barrier wall, the impacted vadose zone below old ponds P2 and P3, and the impacted vadose zone below units 4 and 5.

In February the “dead zone” wells M-70, M-71, and M-72, were redeveloped and pump tested and found to be extremely poor water producers. Table 2 of the accompanying *Groundwater Capture Evaluation* (Appendix B) shows that the best of the three wells, M-70, could only pump a maximum of 0.625 gpm and that the total pumping amount from the three wells is only about 0.75 gpm. This condition is complicated by the fact that at this time the groundwater mound formed by injection of water into the recharge trenches had dissipated because of the clogging of the trenches. Now that the north trench has been refurbished it is expected that water levels will rise in the dead zone wells and that the wells could still be pumped at a rate of 1 to 2 gpm over the span of approximately 9 to 12 months to “mine” water from this area and reduce the total chromium impact. It should be noted that while the mound was low, some of the chromium migrated downgradient.

Capacity to handle the water in the GWTP has been made available by rerouting water from GW-11 directly to the equalization tanks, and more capacity can be made available by routing the discharge from selected wells connected to the west header, directly to the GW-11 pond. A discussion of this issue is presented in the *Groundwater Capture Evaluation* (Appendix B).

The former P2 and P3 pond areas and the subsurface impact below Units 4 and 5 could potentially be treated with amendments to reduce the hexavalent chromium to the relatively insoluble form (chromium III). This may be a viable approach to remediation of the vadose zone impact in these areas and will be investigated after the Source Area Investigation portion of the Environmental Compliance Assessment (ECA) program is completed. At that time, if any other chromium-impacted areas are found, all existing impacted source areas can be treated together in a more efficient and cost effective manner. Similarly, if other site-related chemicals are identified in the area during the Source Area Investigation, the potential impact of the chromium treatment option can be considered.

4.0 PERCHLORATE RECOVERY PROGRAM

The four components of the perchlorate recovery system, consisting of the on-site Interceptor well field, the off-site Athens Road well field, the off-site Seep well field and the off-site Seep surface-flow capture sump, are shown on Figure 1. In the first half of 2008, a total of about 276,632 pounds of perchlorate (1,520 pounds per day) have been removed from the groundwater with the overall system. Of this total, about 149,994 pounds (824 pounds per day) came from the on-site Interceptor well field, about 116,843 pounds (642 pounds per day) came from the Athens Road well field, about 9,795 pounds (54 pounds per day) came from the Seep well field and zero pounds came from the Seep surface-flow capture sump. For the last 12 months, since July 2007, a total of about 563,890 pounds of perchlorate have been captured, removed, and destroyed in the biological treatment system. Figure 11 shows the 2008 monthly perchlorate recovery totals and the relative significance of each of the four components, and Table 6 shows the average pounds of perchlorate per day removed by each component. The recovery over the last quarter was lower than pervious periods because of significant decreases in perchlorate loading available for capture at the three well fields due to the changes in plume concentrations. Note also on Table 6 that the June 2008 recovery is an estimate that will be recalculated next month.

4.1 Perchlorate Plume Configuration

Plate 4, the *Perchlorate in Groundwater* map, shows the contoured perchlorate plume from the Tronox plant site to Las Vegas Wash based on data collected in May 2008. The effects of the Interceptor well field, the groundwater barrier wall, the groundwater recharge trenches, the Athens Road well field, the Seep well field and the Seep surface-flow capture sump are evidenced by the significant reduction of perchlorate concentration downgradient of the barrier wall.

4.1.1 Interceptor Well Field Area

The three components of this well field area, the recovery well line, the barrier wall, and the groundwater recharge trenches, significantly reduce the amount of perchlorate in the downgradient groundwater. As shown on Plate 4, the barrier wall has cut off most of the downgradient movement of groundwater containing high perchlorate concentrations. In the vicinity of the downgradient recharge trenches, concentrations down to non-detect (ND) (>0.004 mg/L) have been mapped. Part of this decrease is attributable to the effects of dilution and dispersion from clean water infiltration in the recharge trenches. Just east of this area of low perchlorate, well M-86 perchlorate levels have increased from 295 mg/L in May 2007 to 649 mg/L in May 2008. This increase is attributable to the dissipation of the groundwater mounding from the recharge trenches and movement of dead zone groundwater downgradient. With the completion of the refurbishment of the trenches, this condition is expected to reverse itself.

Figure 12, the *Interceptor Well Field Perchlorate Section Graph*, shows the perchlorate concentrations for the Interceptor wells in May 2002 and over the last four quarters. These data are more variable than the total chromium data shown on Figure 7. The most recent quarterly data from May 2008 show that the perchlorate concentrations in many of the Interceptor wells are significantly lower than in May 2002 and many wells are at or near their historic lows. Note that well I-Q shows the same abrupt decline in perchlorate concentration as the chromium concentration shown in Figure 7.

Based on this graph and Figure 13, the *Interceptor Well Field Perchlorate Trend Graph*, since at least May 2002 there have been two sub-plumes impacting the well field (a major plume east of well I-M and a minor plume west of I-M) that the overall perchlorate loading is declining over time. On the west end of the barrier wall, perchlorate levels in Interceptor well I-B have continued to decrease from 3000 mg/L in May 2006 to 825 mg/L in May 2008. Perchlorate levels in monitoring well M-69 (directly downgradient from I-B) which had been increasing since mid-2005, have now begun to dramatically decrease (1350 mg/L in November 2006 to 420 mg/L in May 2008). The reason for this decline is probably the increased pumping in upgradient well I-AR. Tronox installed additional monitoring wells and one recovery well west of I-B, which will be connected to the well field in late 2008 or early 2009. A discussion of this work is presented in the *Groundwater Capture Evaluation* (Appendix B). In order to present recent data in a meaningful way, the last five quarters of data from Figure 13 have been expanded and are shown on Figure 13A.

Since high perchlorate concentrations are often associated with high total dissolved solids (TDS) concentrations, a TDS section graph was constructed across the well field. A comparison of Figure 12 and Figure 14, the *Interceptor Well Field Total Dissolved Solids Section Graph*, shows that the broad zone of high TDS in the central part of the well field continues in the most recent sampling without a concomitant increase in perchlorate concentrations. It is also noteworthy that the high perchlorate plume on the west side of the well field is not associated with high TDS. It is thought that a groundwater pulse containing a high concentration of perchlorate, with no other salts present, is responsible for this anomaly. Note that well I-Q shows the same drop in TDS concentrations as that seen for perchlorate and chromium.

The monthly average perchlorate concentration collected at the well field has been decreasing, with short-lived minor reversals, from a high of about 1,900 mg/l in 2002 to about 1,001 mg/l in June 2008 (see Figure 15). This figure also shows the monthly average perchlorate removed from the groundwater which is estimated to be 22,115 pounds in June 2008; reflecting the decreasing perchlorate mass available for capture. Data from monitor well M-100, seven hundred feet north of the recharge trenches, demonstrate that the recharge trenches were effective up until about May 2007 when their slow clogging started to choke off the water supply to M-100. As shown in Figure 16, the historic perchlorate concentration low in this well (13 mg/L) occurred in May 2007 and was 98 percent less than the January 2002 concentration of 1000 mg/L. Since the refurbishment of the trenches in March/April, the groundwater elevation is rising once more which demonstrates that the groundwater mounding effect from the trenches reaches at least to this well.

4.1.2 Athens Road Well Field Area

The Athens Road well field was completed in March 2002 and groundwater collection in this area began shortly thereafter. Continuous pumping from this well field began in mid-October 2002. In September 2006, an additional recovery well (ART-9) began full-time pumping. Figure 1 and Plates 2 and 4 show the location of the Athens Road well field. As of June 23, 2008, the pumping Athens Road wells were ART-2, 3A, 4A, 7, 8 and 9 and the June 2008 recovery well discharge rate was about 271 gpm (Table 2). Appendix A presents groundwater elevations and analytical data from the wells in this area. *The Perchlorate in Groundwater* map, Plate 4, based on May 2008 sampling, shows that the concentrations in the main body of the plume decrease dramatically between Warm Springs Road and Las Vegas Wash .

The perchlorate concentrations of the ART-series wells are shown in Figures 17 and 17A. The trend lines on Figure 17 show that between January 2003 and September 2006 the perchlorate concentrations were basically stable with only minor variations and that after September 2006 perchlorate concentrations in all wells began to accelerate their decline. Figure 17A, an expanded view of the last five quarters of Figure 17, shows that since April 2007, perchlorate concentrations in ART-8 have decreased from 321 to 222 mg/L and perchlorate concentrations in ART-1, 2, 5 and 7 have essentially remained constant or decreased slightly. Perchlorate concentrations in ART-6, currently the highest at 340 mg/l, increased dramatically back to historic levels in October 2007, only to decrease again in March 2008 and increase once more in April. Tronox is working to put ART-6 back on-line by the fourth quarter and recover groundwater from the well. Groundwater from well ART-9, currently pumping at about 43 gpm, contains 316 mg/l of perchlorate, down from 385 mg/L at the commencement of pumping in September 2006. Figure 18, an east-west section graph through the well field, shows that over the last four quarters the concentration changes have occurred in a narrow range – with the exception of ART-6 – and that most of the present concentrations are below those from May 2002. Note that the perchlorate concentrations on the western (PC-55 and ART-1) and the eastern sides of the well field (PC-122) continue to remain very low. The monthly perchlorate concentration in ART-8, as shown on Figure 19, currently contains 222 mg/L - at the low end of its range. Also shown on this graph is the monthly average perchlorate mass removed from the well field, which was estimated to be 19,116 pounds in June, reflecting the declining perchlorate mass available for capture.

Starting in August 2006, TDS data have been collected from the well field. A section graph, Figure 20, shows that two zones of higher TDS exist at the well field centered on ART-8 and PC-17 on the west (9600 mg/L maximum) and ART-7 and PC-122 on the east (9850 mg/L maximum).

About 250 feet north of the Athens Road well field, seven ARP-series wells and one MW-K series well make up the Athens Road piezometer well line. The perchlorate concentrations of these wells, completed in December 2001, are shown in Figures 21 and 21A. The western two wells, ARP-1 and 2, and the eastern well, ARP-7, continue to contain perchlorate concentrations below 5 mg/L. In mid-April, ARP-3 contained 10 mg/L perchlorate, down from 660 mg/L in January 2003. In December 2007, ARP-4A, 5A and 6B replaced ARP-4, 5 and 6A which were plugged and abandoned to make way for COH WRF drainage ditch construction. Perchlorate concentrations in MW-K4 (located east of ARP-3) declined significantly in 2006, only to rise in early 2007, and decline again to 57.8 mg/L in June 2008. Figure 22, an east-west section graph across the piezometer line, shows the sharp decline in perchlorate concentrations since May 2002 in the western sub-channel. Figure 23 shows the steep decline in perchlorate concentration in well ARP-3 over the last four years as a result of the efficient recovery at the well field. It is expected to take longer to clean the piezometer line wells because pumping at the Athens Road well field and periodic discharge by COH WRF has flattened the hydraulic gradient in the area of the piezometers. Currently, the Athens Road well field area, extending north to the piezometer line, is undergoing extensive construction activities. Periodically wells are buried or damaged. Currently, PC-134 has a damaged surface completion and ARP-2, 3, 7 and PC-137 are buried. Tronox is working to repair or replace damaged wells and to minimize future damage as COH WRF modifications continue.

Intermediate between the Athens Road area and the Seep area are the COH WRF and the Lower Ponds monitor well lines. Figures 24 and 24A show the perchlorate concentrations in the COH WRF wells from January 2001 to mid-June 2008. As shown, wells PC-98R and MW-K5, in which concentrations have previously been erratic prior to April 2004, have varied in a narrow range of 8.8 to 25.0 mg/L and 2.3 to 16.9 mg/L, respectively, since May 2007. As of mid-June 2008, PC-98R and MW-K5 contain 19.0 and 11.5 mg/L perchlorate, respectively. Figure 25, the east-west section graph, shows that for the last four quarterly reporting periods, the perchlorate concentrations in the well line have declined to or near their historic lows. Figure 26, the *PC-98R Perchlorate vs. Water Elevation Trend Graph*, shows that since February 2003 the groundwater level has continued to generally decline, but significant groundwater “mounding events”, due to increased COH WRF surface water infiltration, continue to occur sporadically. It is significant to note on this graph that since December 2003, a spike in perchlorate occurred during each spike in groundwater elevation. This indicates that during higher water levels, additional perchlorate from the vadose zone was put into solution and that the historic higher-than-normal perchlorate concentrations in this well line are more a function of COH WRF discharge than presumed perchlorate leakage past the Athens Road well field. However, during the latest five mounding events occurring since May 2007, this has not been the case. This suggests that much of the perchlorate in the vadose zone in this area has been removed.

The Lower Ponds well line is 2200 feet north of the COH WRF well line. Figures 27 and 27A, the *Lower Ponds Well Line Perchlorate Concentrations Trend Graphs*, shows that perchlorate concentrations have not varied much since about February 2004. The last five quarters of data shown on Figure 27A are essentially flat. As of June 2008, PC-59 contains the highest concentration at 7.1 mg/L. Figure 28, the *Lower Ponds Perchlorate Section Graph* and Plate 4, shows that in May 2008, PC-58 contained the highest perchlorate concentration (8.5 mg/L) along the well line. However, as mentioned above, June data show that PC-58 has decreased to 2.9 mg/L and is expected to drop further in coming months as the lower concentration groundwater from the COH WRF area reaches the well line.

4.1.3 Seep Well Field Area

The original three recovery wells in the Seep well field went on-line in August 2002. In February 2003, five additional wells (PC-117 to PC-121) were completed and in December 2004, one additional well (PC-133) was completed in the Seep well field (Figure 1, Plates 2 and 4). At present, the Seep well field consists of ten wells – two of which (PC-99R2 and PC-99R3) are connected and operate as one – positioned over the deepest part of the alluvium channel that contains the highest concentrations of perchlorate. The well field is located about 600 feet upgradient of the seep surface-flow capture sump. Plate 4 and Figures 29 and 29A show the regional and detailed depiction of the perchlorate content of the wells, respectively. Figure 25A shows that over the last five quarters, the two wells with the highest perchlorate (PC-99R2/R3 and adjacent well PC-115R) are currently declining and all wells currently contain less than 9.5 mg/L perchlorate.

Recent mapping of the perchlorate concentrations (shown on Plate 4) suggests that the strong pumping of the Seep well field is drawing in water from the Wash to the north. Table 3 contains the June 2008 discharge rates from the individual wells and the total for the well field (631 gpm total). Additional evidence for incoming Las Vegas Wash water comes in the form of greatly reduced perchlorate and conductivity concentrations in PC-96 and PC-97, north of the well field. For example, the perchlorate concentration in PC-96 has declined from 28 to 0.67 mg/L since May 2001, whereas the concentrations in PC-97 have declined from 96 to 0.55 mg/L over the same period (see Figure 30 and Appendix A). Figure 30 also shows that in the past, when the groundwater level increased in the winter, there was a concomitant bump in perchlorate concentration; however, this did not occur this past winter. This situation will continue to be monitored and may result in a further decrease of the pumping rate.

Figure 31, the *Seep Well Field Perchlorate Concentration Section Graph*, shows that the concentrations from the May 2008 sampling are little different from concentrations over the last four quarters. Data from May 2002 are shown for comparison. TDS concentrations for the last four quarters are plotted on Figure 32. This figure shows that the highest TDS concentration (4040 mg/L) is currently from PC-115R, the well containing the highest perchlorate. Figure 4 shows perchlorate concentrations from May 2008 in cross-sectional format.

The monthly perchlorate concentration, as shown on Figure 33, currently averages about 5.6 mg/L. Also shown on this graph is the monthly average perchlorate mass removed, which was estimated to be 1,311 pounds in June 2008. This graph shows that decreasing perchlorate concentration is responsible for decreasing perchlorate pounds removed.

The May 2008 Southern Nevada Water Authority (SNWA) sampling of five vegetation irrigation wells (plotted on Plate 4) completed in Las Vegas Wash show that these wells all contain less than 4.4 mg/L perchlorate. Well WMW6.15S which contained 45.6 mg/L perchlorate in June 2002, contained 0.9 mg/l perchlorate in May 2008; evidence that the in-place recovery systems are functioning well. As plotted on Plate 4, the 1 mg/L groundwater perchlorate contour is only about 700 feet downgradient of the Pabco structure.

As shown on Figure 34, the seep stream ended its flow in mid-April 2007. The relationship of higher winter flow/water elevation and higher perchlorate concentration in water, evident back to the winter of 2002, did not occur this winter.

4.2 On-Site Perchlorate Groundwater Treatment System and Remediation

Groundwater collection and operation of the biological treatment plant continued throughout the reporting period. In the first quarter of 2008, the bioplant experienced difficulty meeting the minimum pH required by the NPDES discharge permit. Higher ratios of perchlorate to chlorate in the bioplant feed resulted in two exceedences of the pH 6.5 minimum. The situation was rectified by expanding the caustic (25 percent sodium hydroxide solution) pH control system. For the last several months since the modifications, caustic usage has totaled about 330 gallons per day to maintain pH levels within permit limits. Routine maintenance is completed as needed at the GWTP and FBRs.

Transfers of dissolved perchlorate from the AP-5 pond to GW-11 in the first six months of 2008 total 126 tons. This brings the total perchlorate removed from the pond to 892 tons, or 89 percent of the perchlorate originally estimated to be in the AP-5 pond. Sampling of the remaining pond solids was conducted in April 2008 using a boat and a hand auger. Care was taken to avoid getting closer than 12 inches from the pond liner. Results of the sampling indicate that perchlorate crystals remain in the solids of the northwest quadrant of the pond. No crystals were found in the other three quadrants. Efforts are currently focused on circulating water in the northwest quadrant to break up the remaining solids and dissolve the perchlorate crystals. Once the crystals have been dissolved, the pond solids can be removed, washed and disposed of in an off-site landfill (likely in 2009).

As shown on Table 7, since July 2006 the perchlorate influent to the FBR has ranged from 197 to 312 mg/L, whereas the effluent discharged to Las Vegas Wash was mostly non-detect at < 0.004 mg/L perchlorate.

5.0 OTHER MAPPED ANALYTES

5.1 Total Dissolved Solids (TDS)

Plate 5, the *Total Dissolved Solids (TDS) in Groundwater,* map, shows the contoured TDS configuration from the Tronox plant site area to Las Vegas Wash based on data collected in April and May 2008 by Tronox and in January and February 2008 by TIMET. The map shows that the Tronox facility is sandwiched between two high TDS zones. High TDS on the Tronox site occurs up to 19100 mg/L in Interceptor well I-U. Between the barrier wall and the Wash there are no TDS concentrations above 9850 mg/L (ART-7). Figures 14, 20 and 32 show, in section graph format, the distribution of TDS across the Interceptor, Athens Road and Seep well fields, respectively.

5.2 Chlorate

Plate 6, the *Chlorate in Groundwater* map shows the contoured chlorate configuration from the Tronox plant site to Las Vegas Wash based on data collected in April and May 2008 by Tronox. The map shows that upgradient of the barrier wall, well M-36 contains the highest chlorate concentration at 8150 mg/L. The two closest downgradient wells north of the barrier wall, M-23 and M-48, contain 433 and 494 mg/L, respectively. Concentrations continue to decrease northward toward the Wash. It should be noted that the biological treatment plant also destroys chlorate from water treated for perchlorate removal.

5.3 Nitrate

Plate 7, the *Nitrate in Groundwater* map, shows the contoured nitrate configuration from the Tronox plant site to Las Vegas Wash based on data collected in April and May 2008 by Tronox and in January and February 2008 by TIMET. The map shows that upgradient of the barrier wall, well M-37 contains the highest nitrate concentration at 119 mg/L. The two closest downgradient wells north of the barrier wall, M-23 and M-48, contain 53 and 17.8 mg/L, respectively. Concentrations continue to decrease northward toward the Wash. It should be noted that the biological treatment plant also destroys nitrate from water treated for perchlorate removal.

6.0 CONCLUSIONS

Chromium concentrations in monitor wells immediately downgradient of the on-site groundwater barrier wall show a marked decline in concentration due to a combination of groundwater capture in the Interceptor well field and dilution by Lake Mead water in the recharge trenches. The north trench has recently been refurbished and the Interceptor wells redeveloped. Groundwater recovery from the Interceptor well field has substantially increased due to the effectiveness of the groundwater barrier. For the twelve month period ending in June 2008, using an average of 13.7 mg/L total chromium and an average groundwater recovery rate of 60 gallons per minute, the chromium recovery and treatment system captured about 9.9 pounds of chromium per day for a total of about 3,605 pounds. Adding the 476 pounds of chromium removed by the FBRs for the twelve month period, a total of 4,081 pounds of chromium were removed from the groundwater between July 2007 and June 2008. Ongoing assessment and monitoring will continue during 2008 to monitor capture of the chromium- and perchlorate-impacted groundwater upgradient of the groundwater barrier.

Chromium capture at the Athens Road well field is expected to be improved with the recent addition of recovery well ART-9 in the eastern portion of the plume and the planned re-initiation of pumping from the ART-6 well. Overall recovery of chromium-impacted groundwater in this area has aided in reducing the plume to non-detect levels prior to reaching Las Vegas Wash.

Perchlorate continues to be captured by the four components of the remediation program. The on-site Interceptor well field, coupled with the groundwater barrier wall, provides capture in this on-site area. Based on the multiple lines of evidence of capture zone, flow budget, downgradient concentration declines over time, and overlapping cones of depression, the Interceptor well field demonstrates upwards of 90 percent capture efficiency.

Since October 2002, the Athens Road area well field has been in continuous operation and is maturing into an efficient interception line. Based on the multiple lines of evidence of capture zone, flow budget, downgradient concentration declines over time, overlapping cones of depression, and numerical modeling, the Athens Road well field demonstrates more than 99 percent capture efficiency

The Seep well field and the seep surface capture make up the remaining portions of the perchlorate recovery system. The Seep well field is advantageously located over the main part of the alluvium channel and is in close proximity to Las Vegas Wash. Capture in this area makes the most immediate impact on Wash perchlorate concentrations. The perchlorate concentration in seep area groundwater is continuing to decrease with minor reversals partly due to periodic groundwater mounding events from the COH WRF. It is anticipated that the impact of continued pumping at the Athens Road well field, especially with ART-9 online, will continue to be observed in the seep area concentrations, modified by discharge activities at COH WRF. Based on the multiple lines of evidence of capture zone, flow budget, downgradient concentration declines over time, and overlapping cones of depression, the Seep well field demonstrates upwards of 98 percent capture efficiency.

A detailed discussion of the evidence for capture efficiency is presented in Appendix B. *Groundwater Capture Evaluation.*

As the ultimate measure of the effectiveness of the combined systems over the last nine years, one need look no farther than the decrease in perchlorate loading in Las Vegas Wash since 1999. In May 1999 the perchlorate loading in the wash was 1,104 pounds/day versus 58 pounds/day in June 2008, a 94.7 percent drop.

7.0 PROPOSED FUTURE ACTIVITIES

Tronox is committed to hook up the new recovery well in the Interceptor well field as well as "mining" groundwater from the three dead zone wells. In order to capture more groundwater at the Athens Road well, field recovery well ART-6 will be put back on-line. Three monitoring wells remain to be installed in the Seep well field as part of the Groundwater Capture Work Plan. This work will begin soon after an access agreement is signed.

Tronox will continue to record water levels in the Consent Order and AOC areas. Potentiometric surface maps will be developed as well as chromium and perchlorate in groundwater maps. The effect of changing the pumping rates of the recovery wells will be monitored, and responses (i.e., pump rate adjustments) will be made to ensure optimal drawdown and plume interception at the well fields. Pumping wells will be rehabilitated as necessary. The monitoring plan in current use will be modified, as necessary, to facilitate collection of pertinent data to track the progress of chromium and perchlorate capture at the well fields and the seep.